Space Weather Technical Forecast

Issued on Tuesday, 09 May 2023 at 13:39 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: G1/G2 Minor/Moderate geomagnetic storm conditions expected late 10 into 11 May. S1/Minor Solar Radiation Storm ongoing. Further R1/R2 Minor/Moderate radio blackouts expected.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has remained Moderate over the past 24 hours, with several M-class flares observed, all from AR3296 (Dac/Beta-Gamma-Delta) in the northwest, peaking at 09/0354 UTC with a M6.5 flare. This sunspot group is a moderately sized, but complex region containing at least one delta spot and rapidly evolving intermediate spots. The largest region, AR3297 (Ehc/Beta-Gamma) in northern centre disc appeared largely inactive, although some penumbral development surrounding the large mature positive polarity spot has occurred. These sunspots are among ten on the current disc, with five numbered and five unnumbered regions. All others are small and/or simple regions at present.

A number of CMEs were observed leaving the sun in the past 24 hours. Analysis of these features is complicated due to limited coronagraph imagery and faint ejecta signatures in some cases. Overall, the majority if not all of the ejecta appears to be well-ahead or behind of Earth orbit, however, some Earth-directed component cannot be completely ruled out.

Solar Wind / Geomagnetic Activity: The solar wind, as recorded by DSCOVR at L1, was mainly indicative of a positive polarity fast wind, most likely that from CH01 or perhaps CH99 given the mainly positive phi angle (away from the Sun). This became less clear-cut later in the period and eased, with a period spent in negative phi signposted by possible SSBCs at 08/1300 and 08/1700 UTC. The solar wind rose from elevated levels near 500km/s to reach an peak of around 550km/s at 08/1552 UTC, before moderating thereafter, becoming slightly elevated and close to background by the end of the period. The solar wind density was mainly at average levels. The IMF fell from an early peak of 8nT (moderate) at 08/1338 UTC to become weak. The north-south component varied weakly, with a peak of +/- 7nT. Resultant geomagnetic activity was Quiet to Active (Kp1-4).

Energetic Particles / Solar Radiation: High energy proton flux (greater than 10MeV), as measured at GOES16, surpassed the S1 threshold very early in the period, rising to a peak of 38pfu at 09/0150UTC. High energy electron flux (greater than 2MeV), as measured at GOES16, has been at Normal Background levels. The 24-hour integrated fluence has been well below Active levels. At 09/0001UTC 1.3e6 integrated pfu was recorded.

Four-Day Space Weather Forecast Summary

Solar Activity: Occasional Moderate activity is expected to continue, with further M-flares likely and a slight chance of isolated X-class flares.

Solar Wind / Geomagnetic Activity: A near-full halo CME was observed in coronagraph imagery with the M1.6 flare from AR3296 at 07/2323UTC. Although much of the ejecta appears to be directed towards the northwest an Earth-directed component is expected and has been modelled to arrive at Earth either on late 10 or early 11 May.

A number of CMEs were observed leaving the sun on 08/09 May. Overall, the majority if not all

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of the ejecta appears to be well-ahead or behind of Earth orbit, however, some Earth-directed component cannot be completely ruled out from 11 May onwards.

Earth is currently in a declining fast wind regime. Slightly elevated winds should soon ease to background through the first 24 hours of the forecast. A minor resurgence in the solar wind may occur late on 11 May due to yet another positive polarity coronal hole - CH02/+. Any impacts are expected to be weak based on persistence, in any case most likely swamped by the concurrent arrival of the CME (detailed above).

On 09 May Quiet to Unsettled activity is expected, giving way to an expected G1-G2 (Minor to Moderate) storm, either late on 10 May or else early 11 May, with a chance of G3 (Strong) geomagnetic storm levels being reached. This risk should recede to a chance of G1 by 12 May given uncertainties in recent CMEs.

Energetic Particles / Solar Radiation: The high energy (greater than 10 MeV) proton flux is likely to remain above S1 on 09 May but with a declining trend unless any response from the M6.5 event from AR3296 at 09/0354 UTC is observed. The chances of S1 being maintained after midweek should fall - in the absence of further significant flare activity.

High energy (greater than 2MeV) electron flux is expected to persist at normal background to moderate levels, with a possibility of reaching diurnally high levels on 10 May ahead of the anticipated CME arrival either late 10 or early 11 May. The associated 24-hour fluence is forecast to persist below the Active threshold.

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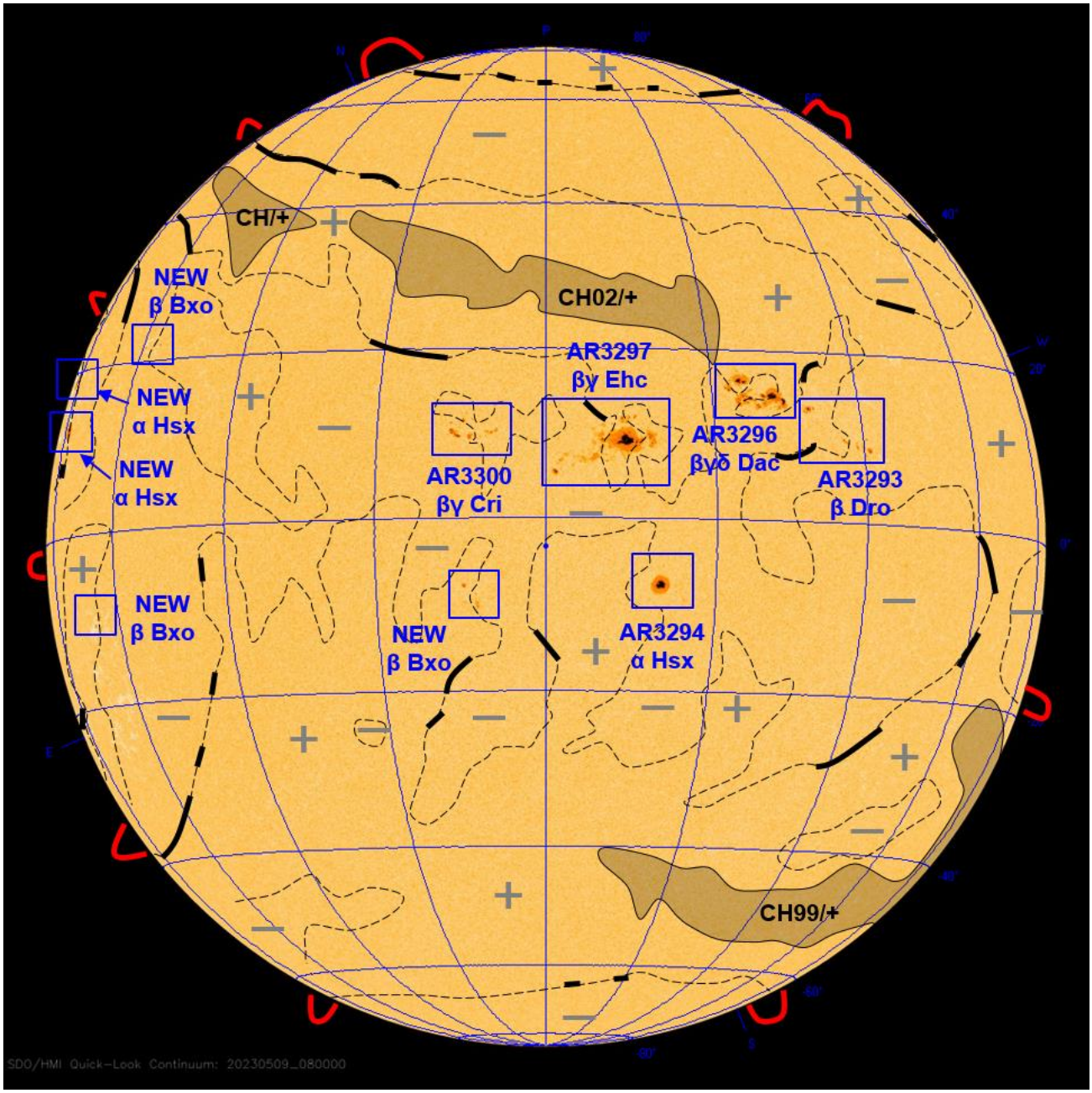
Figure 1. Solar Analysis Valid 09/0800 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

A near-full halo CME was observed in coronagraph imagery with the M1.6 flare from AR3296 at 07/2323UTC. Although much of the ejecta appears to be directed towards the northwest, an Earth-directed component is expected and has been modelled to arrive at Earth either late on 10 May or early 11 May.

A number of CMEs were observed leaving the sun in the past 24 hours. Analysis of these features is complicated due to limited coronagraph imagery and faint ejecta signatures in some cases. Overall, the majority if not all of the ejecta appears to be well-ahead or behind of Earth orbit, however, some Earth-directed component cannot be completely ruled out from 11 May onwards.

Earth is currently thought to be under the waning influence of a positive polarity fast wind, namely that from CH99/+ and/or CH01/+. Slightly elevated winds are expected to soon ease to background on 09 May. Some enhancement in the solar wind may then occur late on 11 May due to CH02/+, however any impacts are expected to be weak based on persistence and most likely masked by the expected arrival of the CME that left the sun on 07 May. Solar winds are most likely to increase to elevated or perhaps strong levels with the CME, probably decreasing to slightly elevated by the end of 12 May.

On 09 May Quiet to Unsettled activity is expected, giving way to an expected G1-G2 (Minor to Moderate) storm, either late on 10 May or else early 11 May, with a chance of G3 (Strong) geomagnetic storm levels being reached. This risk should recede to a chance of G1 by 12 May given uncertainties in recent CMEs.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	5	80	80	20
Strong	G3	No	1	20	20	1
Severe	G4	No	1	5	5	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
08/0300	Near-full	Flare	AR3296	950 km/s	10/2100 UTC +/- 9 hours	N/A

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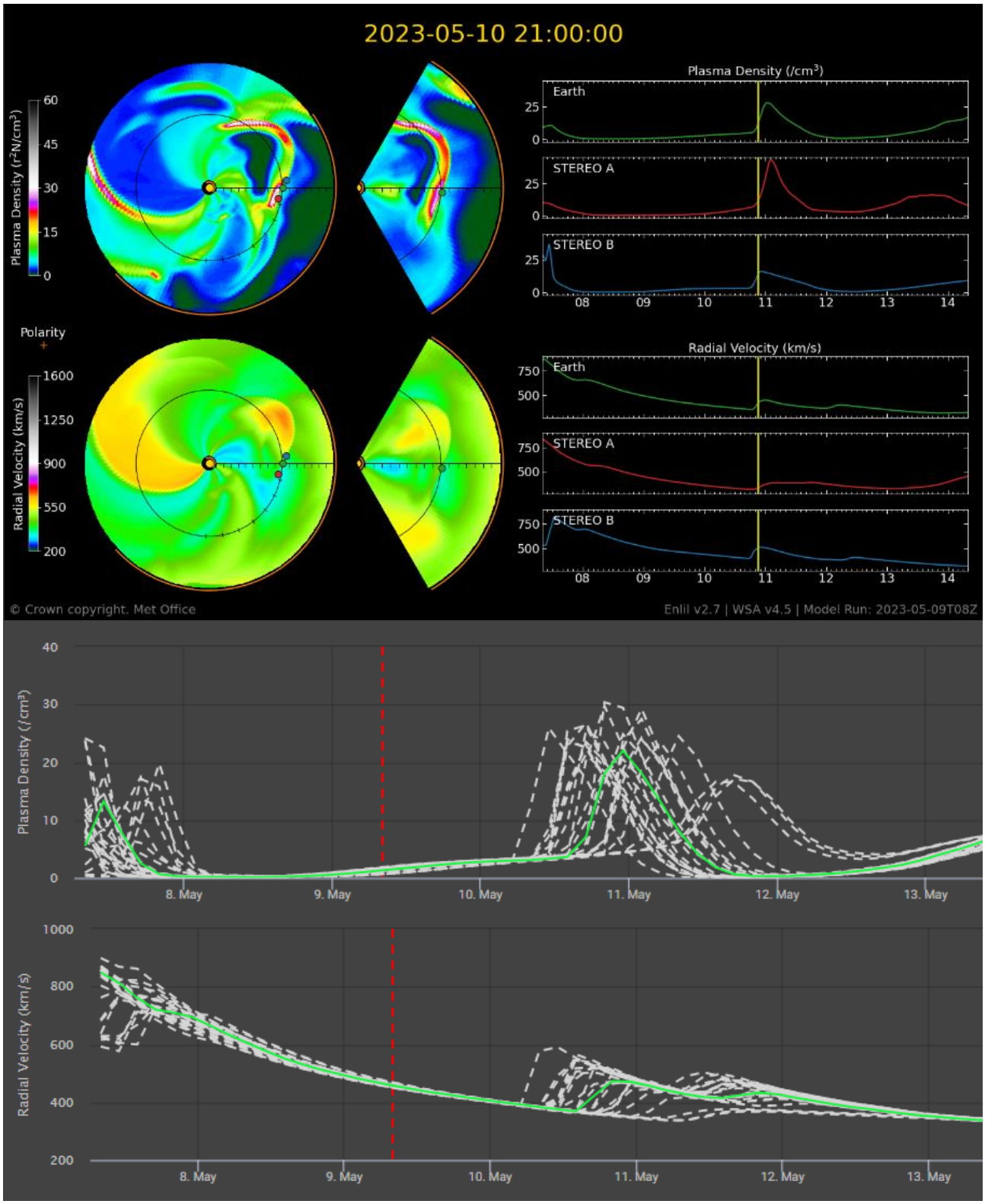
Figure 2: Latest MOSWOC Enlil run and ensemble



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Radio Blackouts - X-Ray Flares:

Occasional Moderate activity is expected to continue, with further M-flares likely and a slight chance of isolated X-class flares.

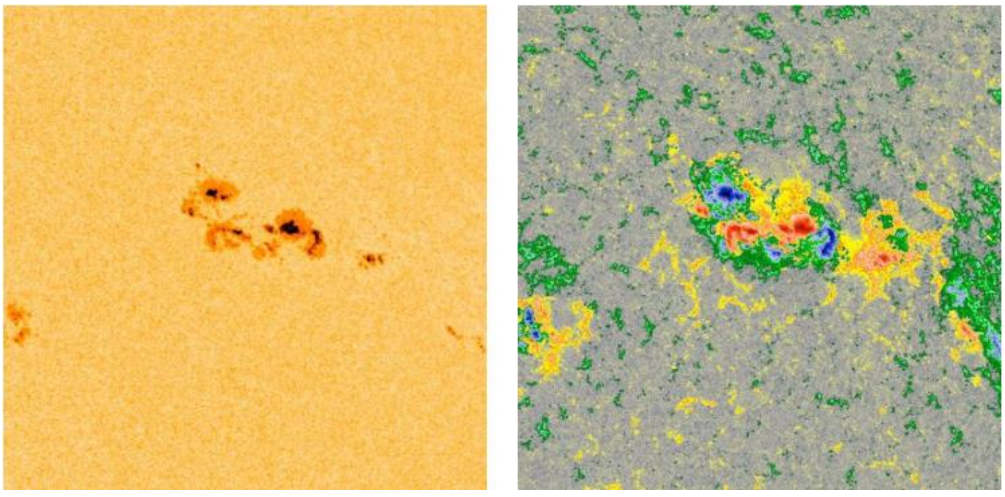
There are currently ten sunspot regions on the visible disc; five numbered and five unnumbered. AR3296 (Dac/Beta-Gamma-Delta) in the northwest remains the most notable sunspot group with the majority of recent significant flare activity from this region. The main changes in the past 24 hours have been a rapid emergence of some southern intermediate spots in AR3296, one of which has migrated west to form a delta spot with the main penumbrae, with a second smaller candidate now possibly also present in its intermediate region. AR3297 (Ehc/Beta-Gamma) saw spot development around its main penumbral spot, with some mixed magnetic field areas sharing penumbra, however, no delta spots are evident at this time.

A number of new regions are either rotating over the eastern limb, or emerging in the eastern hemisphere. The most notable recent growth is from the region east of AR3297, New (Cai/Beta) with penumbra now forming on the trailer portion of the group.

Regarding the balance of sunspot regions on the Earth-facing side, none of the significant contributors to the Likely M-class risk leave the disc in the period, and there are no significant returning regions due, leading to a flat four-day trend.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	80	80	80	80
Very Active	R3 to R5 X Class	No	10	10	10	10

Figure 3: AR3296 as seen by HMI Intensitygram (left) and HMI colorized magnetogram (right)



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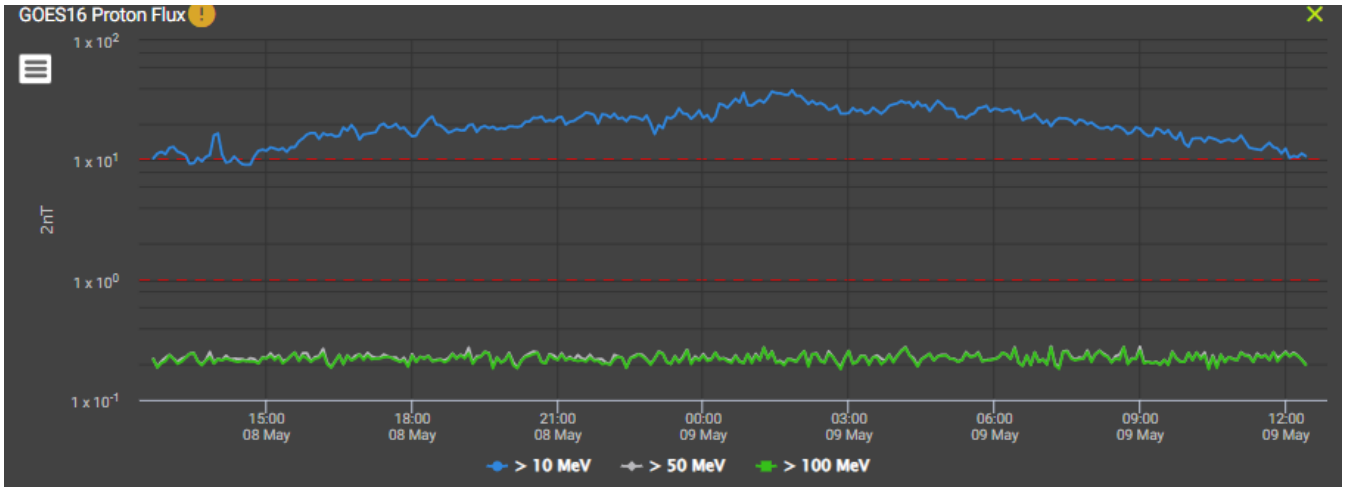
Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux, as as observed by GOES16 passed the S1 threshold in response to the long-duration M1.6 flare from AR3296 at 07/2323UTC and remains at S1 levels at the time of issue. Further flares from the same region may have generated still more Earth-connecting protons, however, in general a very gradual reduction back to background levels should occur in the coming days. The proton forecast is thus relatively low confidence, as the current gradual decline is reliant on there being no further significant events while the flux is elevated at GEO. Raw disc probabilities suggest a 20% daily chance of their occurrence.

All considered, S1 is expected for at least 09 May, perhaps with a further increase possible given the M6.5 flare from AR3296 at 09/0354 UTC, but probably falling short of S2 levels. Probabilities of S1's continuation should fall later in the UTC week, but remain slightly above the 20% raw disc probability throughout given the higher than background starting point and AR3296's apparent propensity for proton-rich events.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	Yes	100	50	30	25
Very Active	**≥ S3 ***	No	5	3	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: 24-hour GOES-16 Proton flux traces



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High Energy Electrons Event (≥ 2MeV):

High energy electron flux (greater than 2MeV) observed by GOES16 is expected to persist at normal background to moderate levels, with a possibility of reaching diurnally high levels on 10 May ahead of the anticipated CME arrival either late 10 or early 11 May. This is in accordance with persistence and the latest MOSWOC REFM output, both of which would suggest a continuation near current comfortably sub-active fluence levels.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	10	5	5
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

Figure 5: Latest GOES-16 Electron flux (above) and REFM output (below)

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